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An Overview of Military Training

J. D. Fletcher
P. R. Chatelier

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PREFACE

This work was performed for the Under Secretary of Defense for Personnel and Readiness, Readiness and Training Directorate under a task entitled "Development and Assessment of ADL Prototypes."

Advanced Distributed Learning (ADL) developments require collaboration with individuals working on the many different facets of military training. In addition and despite ADL's initial emphasis on military training, these ADL developments increasingly require intensive collaboration with people outside the military in other government, industry, and educational organizations.

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I. INTRODUCTION

Military training means definite but very different things to different people. To the commander of a military unit, it means exercising troops in the field or sailors at sea so that they operate as an integrated, coordinated unit. To military personnel managers, it means preparing and certifying individuals across a full spectrum of occupational specialties that include cooks, dog handlers, tank turret repairers, radar technicians, and fighter pilots. To developers and providers of major military systems, it means exercises performed in simulators or on the systems themselves. To all concerned, it means preparing individuals from a civilian society to perform as professional military personnel.

Military training is distinguished from other forms of training by its emphases on discipline, just-in-case preparation, and the training of collectives. This document is intended to provide a general system-wide overview that will provide a useful perspective on military training for all those involved in developing and assessing prototypes for the Advanced Distributed Learning (ADL) initiative.

II. WHAT IS UNIQUE ABOUT MILITARY TRAINING?

A. TRAINING AS DISCIPLINE

Military training must prepare individuals to enter into harm's way and perform physically and mentally demanding tasks at the highest possible levels of proficiency. This requirement may be the defining characteristic of military training. It can mean the difference between life and death. A common observation among tactical analysts and military historians is that the greatest harm is suffered by military personnel who abandon their tasks, break, and run under the pressures of combat (e.g., du Picq, 1880/1946; Keegan, 1993; Gabriel and Metz, 1992). For these reasons, military commanders often view training as discipline.

Military commanders have held this view at least since the Persian campaigns of 480–479 B.C. in Greece (Dupuy and Dupuy, 1977). In those campaigns, the Greeks relied on the infantry phalanx, which was a trained body of soldiers (hoplites) arranged in long rows that varied in depth from about 8 to 16 men. Training emphasized teamwork and physical conditioning. Each hoplite had to learn how to perform precise phalanx maneuvers. This was not simply a matter of executing close-order drill on parade fields. Maintaining a controlled front while advancing over mixed terrain was critical in the broken and rocky hills of Greece. Each hoplite also had to learn to use his weapons proficiently, to stand and fight without exposing his comrades to flank attack, and to close ranks quickly when others fell.

This training paid off. The Persians fought with greater numbers of troops and displayed dash, elan, and superior generalship, yet they were continually thwarted by the stubborn discipline and training of the hoplites. In the battle of Platea, the Persians shattered their land forces against the Greek phalanxes, losing an estimated 50,000 soldiers to the Greeks' 1,500. Dupuy and Dupuy (1977) echo points made earlier by Herodotus and Thucydides, noting that "the battle [of Platea] was the first won by technical superiority, in the first clear-cut example of the value of superior discipline and training" (p. 28).

Today's infusion of technology into nearly every aspect of military operations has significantly altered the nature of military engagements. It has increased the complexity

of military operations, the number of tasks that individuals must perform, and the demand for knowledge and skill among military personnel (Binkin, 1986; *Technology for the U.S. Navy and Marine Corps,* 1997). The speed and mobility of modern military operations, the lethality and long reach of modern weapons, and the requirements in modern doctrine for dispersion and rapid composition of forces compound this complexity.

To some degree, technology may insulate today's military personnel from the exigencies historically faced by combatants. Instead of charging with shield and sword, they operate increasingly exotic sensors to locate the enemy, guide robotic vehicles toward targets, and push buttons to release weapons. They contend with people whom they never approach in person and, for that matter, may never see. Despite their technology, however, they must still function under lethal threat. As much as we might desire the contrary, modern warfare is not a sanitized, bloodless affair. Military training will never escape its requirement for military discipline.

B. JUST-IN-CASE TRAINING

Most civilian training goes to considerable lengths to avoid just-in-case training and to emphasize just-enough and just-in-time training. Preparing individuals to perform tasks that are rarely—if ever—required on the job is viewed as unnecessary, inefficient, wasteful, and generally a poor idea. Military training is different. It must prepare individuals and groups of individuals for armed combat engagements that we hope and often expect to be unnecessary. In this sense, military training is fundamentally just-in-case training, treating as necessary what training in other venues may view as extraneous.

This is not to say that all military training is just-in-case training. Many military tasks are not performed under emergency conditions, allowing time for just-in-time training or job-performance aiding. Still, military training must prepare personnel for armed engagements—for combat. Succeeding very well at this task reduces the need for it. Knowing that they face a well-trained, well-prepared enemy has caused many commanders to withdraw their forces from the field before combat begins. The lethality of modern warfare has increased the deterrence value of armed forces and, thereby, the value of training for combat, but it may also reduce the likelihood that it will occur. Most military operations in recent times have not involved combat. Instead, they involve operations such as peacekeeping, peacemaking, counterterrorism, and humanitarian relief. In recent years, only about 10 percent of major operations undertaken by U.S. armed forces involved armed combat.

Some just-in-case training is, of course, properly included in civilian instruction. Police departments, fire departments, paramedics, emergency crews, and other crews, groups, and teams must be prepared to respond appropriately on very short notice to rapidly developing exigencies. Combat has been described as 98 percent boredom and 2 percent sheer terror. Other civilian occupations similarly require hours of watchful waiting followed by rapid transition to the intense concentrated activity and teamwork needed to meet emergencies. These transitions and the just-in-case training needed to prepare for them are of sufficient general concern that they have been studied by the National Research Council (NRC) (Huey and Wickens, 1993).

A dilemma here seems peculiar to military training. Other training, including civilian training of emergency personnel and crews, is likely to be assessed, sooner or later, by performance in "real-life" situations. Comprehensive assessment of combat skill is both vital and impossible. Such assessment requires the exigent pressures of wartime, which exceed anything that can be provided in peacetime. Moreover, a single combat engagement undertaken to assess the capabilities of a military unit would be insufficient because of the decisive and unique conditions that shape military operations. We would need a representative sample of combat engagements to complete the assessment. The sample would have to be stratified to account for various combinations of air, land, and sea assets; different conditions of weather, terrain, and enemy opposition; and different mission intent. Other variables could be added. Staging a sample of wars to assess combat performance and effectiveness rapidly transcends practicality, to say nothing of ethicality.

Hiller (1987) describes this issue as the "criterion problem" of combat training. We must train individuals and groups of individuals without the benefit of true criterion testing. Given the destructive and horrific nature of modern combat, we can only be glad the problem exists. Still, the issue remains vital. Unless or until deep-seated propensities in human nature can be reversed, provisions for the defense of human societies will continue to be essential for their survival. Societies must provide just-in-case combat training for their armed forces, with some assurance that their forces—and not others—will prevail should such operations become necessary. How to assess the preparedness of military forces for combat engagements presents a compelling and nationally significant challenge for students of human behavior.

C. TRAINING OF COLLECTIVES

Much military training emphasizes collectives: crews, groups, teams, and units. Such an emphasis may be reasonable for military and nonmilitary training. Cannon-Bowers, Oser, and Flanagan (1992), in their review of collectives in industry and business, report a clear "consensus among those who study industrial and organizational behavior that work groups are the cornerstone of modern American industry" (p. 355). However, collective training is uniquely emphasized by military organizations. An increased concern with collective training has been growing in civilian circles (e.g., Swezey and Salas, 1992), but it has yet to match the concentrated intensity it receives in military training.

Collectives are certainly characteristic of military operations. It is difficult to think of any military operation that does not involve the performance of a crew, group, team, or unit. For that matter, many military organizations may not consider the training of individuals as a training issue at all—but as a personnel issue. In this perspective, "training" is what military commanders do to prepare the units they command (the units whose performance is their primary responsibility) to perform the missions to which they may be assigned. Individual "school-house" training to certify members of their units as tank turret repairers, clerks, machine gunners, torpedo technicians, and so forth is a separate, personnel supply activity. It is to be performed by those whose job it is to provide units with qualified individuals to fill personnel "slots." In this sense, individual training is generally viewed not as an investment; rather, it is viewed as an infrastructure cost, lumped together with the costs of transporting personnel from one unit to another, providing for their hospitalization, or even incarcerating them in stockades—a cost that is to be avoided or, at best, minimized.

Many commentators hold this view of training as primarily and perhaps solely as collective preparation on military operations. It is reflected by much that is written about military training (e.g., Collins, 1978). Overall, the concern with collective training and performance is not exclusive—in calm moments, most military commanders recognize the necessity and value of individual training—but, in the military, collective training is emphasized to an extent rarely found in nonmilitary venues.

III. RELEVANCE OF MILITARY TRAINING

Why should those who are interested in civilian training attend to military training? It does after all have the unique emphases discussed previously, but these are differences of emphasis. Issues of discipline to do the work needed, just-in-case preparation for emergencies, and crew, group, team, and unit training are also found in civilian training circles. Aside from these issues, other reasons exist for those responsible for the design, development, and delivery of training to become familiar with military efforts to do the same. Among these reasons are those that stem from the magnitude of military research and development (R&D) in training (particularly R&D on technology applied to training), specific products of military training, practices for designing and developing military training, and procedures for assessing military training programs, especially those concerned with cost and effectiveness.

A. RESEARCH AND DEVELOPMENT (R&D)

Many techniques and technologies developed for military training are also applicable in civilian sectors. The U.S. Department of Defense (DoD) spends hundreds of millions of dollars each year to train the 2.3 million members of its active and reserve armed forces and its 800,000 civilian employees. Since the 1950s, it has spent $150 million to $250 million each year on R&D in education, training, training devices, and simulators. DoD maintains what may be the largest, most extensive training operation in history, accompanied by what may be the largest, most extensive training R&D effort ever undertaken. It would be remarkable if all this activity did not yield some techniques and technologies of general interest and applicability beyond the military.

Defense-sponsored R&D is notable for other reasons. This activity is not intended to achieve proprietary advantage, as it is frequently expected to do in the private sector. For this reason, DoD R&D findings are as freely available for advancing the state of art and practice in civilian training as they are for military education—aside from issues of classification and security. The impact of these findings in the United States has been substantial, as Ellis (1986) documented, but it is often indirect. The findings are likely to be disseminated in technical reports and made available only through the Defense

Technical Information Center (DTIC) or the National Technical Information System (NTIS). Defense researchers may publish their findings in refereed journals but only later and usually with few incentives other than personal satisfaction for doing so.

Still, the transfer of DoD R&D products to civilian practice occurs frequently, thereby indicating their relevance to nonmilitary instruction. Such “technology transfer” can include different devices [e.g., the aircraft simulators used to train military pilots, training packages that constitute programs of instruction in various topics of interest, and techniques such as “intelligent” computer-based instruction (CBI) or computer-based adaptive testing].

Some training devices have been transferred, usually as surplus, to nonmilitary use, but this form of transfer is infrequent. There has been considerable interest in adapting military training packages for application in civilian education and training institutions. This interest does not seem unreasonable. As the next section suggests, many military training programs, packages, simulations, and other materials prepared for military training could find direct application in the civilian sector. However, it is the transfer of techniques developed by DoD R&D funding—rather than devices or training packages—that appears to be most common.

This sort of transfer has occurred to an extent rarely noted or appreciated. Fletcher and Rockway (1986) reviewed the history of military contributions to technology-based instruction. They suggested that DoD funded much, and perhaps most, of the early work on programmed instruction, computer-assisted instruction (CAI), flight simulation, computer-managed instruction (CMI), computer-based/adaptive testing, instructional systems design, interactive videodisc instruction, and intelligent tutoring systems. The U.S. Congressional Office of Technology Assessment (OTA) reviewed these contributions in 1988 and reported that:

> The military has been a major, and occasionally *the* major player in advancing the [educational technology] state of the art. Implications for education in the civilian sector are clear. Computers would probably have found their way into classrooms sooner or later. But without [military support of] work on PLATO, the IBM 1500 system, computer-based equipment simulation, intelligent instructional systems, videodisc applications, and research on cognition, it is unlikely that the electronic revolution in education would have progressed as far and as fast as it has (*Power On!*, 1988, p. 158).

B. PRODUCTS AND PRACTICES IN MILITARY TRAINING AND EDUCATION

A considerable overlap exists between the content of military training and the content of training found elsewhere. Table III-1 shows the diversity of enlisted military careers. The table lists the 12 Standard Occupational Classifications (SOCs) for enlisted military careers and the more descriptive occupational categories associated with each of them. On any day, about 85,000 enlisted personnel will be taking residential training intended to certify them for a military occupational classification or subclassification (*Military Manpower Training Report,* 1999). Each year there are about 900,000 enlisted personnel enrollments in training courses that last from 4 to 72 weeks in length.

Table III-1. Training Required for Military Occupational Specialties

Standard Occupational Code	Occupational Specialty	Weeks of Formal Instruction
Administrative	Administrative Support Specialists	6–10
	Computer Systems Specialists	7–13
	Finance and Accounting Specialists	6–12
	Flight Operations Specialists	7–14
	Legal Specialists and Court Reporters	6–10
	Personnel Specialists	7–9
	Postal Specialists	3–4
	Preventive Maintenance Analysts	4–15
	Recruiting Specialists	4–6
	Sales and Stock Specialists	6–7
	Supply and Warehousing Specialists	4–6
	Training Specialists and Instructors	2–14
	Transportation Specialists	6–9
Combat Specialty	Artillery Crew Members	10–14
	Combat Engineers	None
	Infantrymen	7–8
	Special Operations Forces	Up to 72
	Tank Crew Members	6–9
Construction	Building Electricians	8–12
	Construction Equipment Operators	4–12
	Construction Specialists	5–8
	Plumbers and Pipe Fitters	8–12

Table III-1. Training Required for Military Occupational Specialties (Continued)

Standard Occupational Code	Occupational Specialty	Weeks of Formal Instruction
Electronic and Electrical Equipment Repair	Aircraft Electricians	18–25
	Communication Equipment Repairers	8–40
	Computer Equipment Repairers	25–35
	Electrical Products Repairers	4–22
	Electronic Instrument Repairers	15–30
	Photographic Equipment Repairers	9–32
	Power Plant Electricians	4–17
	Precision Instrument Repairers	12–34
	Radar and Sonar Equipment Repairers	20–30
	Ship Electricians	18–25
	Weapons Maintenance Technicians	15–30
Engineering, Science, and Technical	Air Traffic Controllers	7–13
	Chemical Laboratory Technicians	2–13
	Communications Equipment Operators	9–22
	Computer Programmers	10–13
	Emergency Management Specialists	8–10
	Environmental Health and Safety Specialists	11–19
	Intelligence Specialists	9–24
	Meteorological Specialists	7–18
	Non-Destructive Testers	9–13
	Ordnance Specialists	15–25
	Radar and Sonar Operators	7–12
	Radio Intelligence Operators	17–24
	Space Operations Specialists	17–30
	Surveying, Mapping, and Drafting Technicians	9–31
Health Care	Cardiopulmonary and Electroencephalograph (EEG) Technicians	26–30
	Dental Specialists	9–14
	Medical Care Technicians	7–52
	Medical Laboratory Technicians	12–36
	Medical Record Technicians	6–18
	Medical Service Technicians (“Medics”)	16–54
	Optometric Technicians	9–13
	Pharmacy Technicians	12–17
	Physical and Occupational Therapy Specialists	11–31
	Radiological (X-Ray) Technicians	12–19

Table III-1. Training Required for Military Occupational Specialties (Continued)

Standard Occupational Code	Occupational Specialty	Weeks of Formal Instruction
Human Services	Caseworkers and Counselors	8–10
	Religious Program Specialists	7–8
Machine Operation and Precision Work	Compressed Gas Technicians	14–19
	Dental and Optical Laboratory Technicians	21–26
	Machinists	10–12
	Power Plant Operators	12–25
	Printing Specialists	8–20
	Survival Equipment Specialists	6–12
	Water and Sewage Treatment Plant Operators	8–10
	Welders and Metal Workers	4–15
Media and Public Affairs	Audiovisual and Broadcast Technicians	7–52
	Broadcast Journalists and Newswriters	9–12
	Graphics Designers and Illustrators	12–14
	Interpreters and Translators	7–52
	Musicians	11–24
	Photographic Specialists	7–24
Service	Firefighters	7–11
	Food Service Specialists	9–14
	Law Enforcement and Security Specialists	5–12
	Military Police	8–12
Transportation and Material Handling	Air Crew Members	7–9
	Aircraft Launch and Recovery Specialist	9–13
	Cargo Specialists	2–6
	Flight Engineers	17–24
	Petroleum Supply Specialists	4–8
	Quartermasters and Boat Operators	6–22
	Seamen	6–12
	Vehicle Drivers	7–8
Vehicle and Machinery Mechanics	Aircraft Mechanics	3–17
	Automotive and Heavy Equipment Mechanics	8–29
	Divers	5–13
	Heating and Cooling Mechanics	8–22
	Marine Engine Mechanics	9–24
	Powerhouse Mechanics	12–24

About 16 percent of the total enlisted force is assigned to the five combat specialty occupations shown in Table III-1, and about 25 percent of the people who receive

initial skill training are in these combat occupations. There are, of course, civilian counterparts or closely related activities for many of the jobs performed in combat specialty occupations, but about 84 percent of the remaining enlisted force receives initial skill training and later experience, including on-the-job and advanced skill training, in occupations with fairly direct civilian counterparts.

Examination of occupational preparation for officers exhibits similar proportions. On any day, about 9,000 officers take residential training intended to certify them for a military occupational classification or subclassification (*Military Manpower Training Report,* 1999). Each year, about 56,000 officers enroll in training courses. About 28 percent of these officers prepare for combat specialty occupations, leaving 72 percent who prepare for occupations with fairly direct civilian counterparts.

This is not to suggest that individuals in these other combat support and combat systems support occupations are released from the demands necessarily imposed by military discipline. Many individuals in these occupational categories have been and will be exposed to armed combat. For instance, medical service technicians—even those who declare themselves conscientious objectors—have been recognized and highly decorated for their distinguished, courageous service in combat. However, Table III-1 makes the point that military occupations and training are diverse and concern much that is of general interest and wide applicability elsewhere.

In addition to the skill training requirements suggested by Table III-1, military organizations throughout history have established and maintained activities that in other venues would look very much like basic education. Besides teaching every soldier to swim, the Romans made sure that all soldiers could read and write in Latin (Gabriel and Metz, 1992). Feudal lords who raised regiments in the 16th century also ensured that soldiers in their infantry regiments were sufficiently literate to read written orders and administrative directives (Keegan, 1993). As recruiting grew difficult during World War II and the Korean War, the U.S. Army and Navy enlisted soldiers and sailors who had to be—and were—taught to read and write (Fletcher, Duffy, and Curran, 1977).

Currently, the U.S. armed forces do not recruit individuals who are illiterate, but they do enlist individuals who must improve their verbal and quantitative skills to work in specific occupational categories. The Basic Skills Education Program (BSEP) discussed by Wilson, Golas, and O'Neil (2000) provides one example of the direct transfer that can occur between the military and civilian sector. The Army developed BSEP in the 1980s to improve the basic skills preparation of individuals for specific Army

occupational categories. These occupational categories were of sufficient general interest that, in response to numerous requests, the Army arranged for the preparation and distribution of BSEP for use in civilian training.

In response to a Congressional inquiry, Fletcher et al. (1992) reviewed 4,644 technology-based training products that the U.S. armed forces produced for their own use. They found that 2,718 (about 58 percent) of these products were candidates for civilian application. The "tail-to-tooth" ratio suggested by this percentage of potentially applicable course material is not particularly different from similar ratios found in other countries. This high proportion of potentially applicable training packages suggests that military and civilian training share many objectives, approaches, and strategies in common and that they have much to learn from each other.

To retain skilled and experienced military personnel, military training organizations must attend to the care of their families— including provisions for K–12 education. The U.S. Department of Defense Education Activity (DoDEA) provides or otherwise supports schooling for military dependents. These schools have operated on U.S. military bases and in about 14 countries overseas since 1946. In the 1997–1998 school year, the Department of Defense Dependents Schools (DoDDS) served an estimated 80,000 students in 161 schools and one community college overseas. In the same school year, the Department of Defense Domestic Dependent Elementary and Secondary Schools (DDESS) served an estimated 33,000 students in 70 schools located in 7 states and the Commonwealths of Puerto Rico and Guam.

Military organizations have supported higher education for a long time. In addition to off-duty vocational-technical courses, the U.S. DoD Voluntary Education program provides undergraduate and graduate educational opportunities to U.S. military personnel worldwide. Each of the military Services provide these opportunities through their local education centers. In 1998, more than 6,000 baccalaureate degrees and 4,000 graduate degrees were awarded to participants in the DoD Voluntary Education program. In addition, the three Service Academies provide undergraduate training each year to about 12,000 students. The academies provide the higher education needed by military officers, prepare individuals for specific military activities, and instill commitment to duty, honor, and country—the virtues of military discipline (Forsythe, 1992).

Finally, military organizations require a broad range of knowledge and skills, many of which are available from graduate study at civilian institutions. DoD sponsors graduate education for about 5,000 personnel each year and graduates about

1,000 individuals from the Uniformed Services University of the Health Sciences (USUHS). DoD also provides professional military education, which is intended to prepare officers for the increasingly complex demands of the military profession and the responsibilities they must assume as they progress in their military careers. Nearly all military organizations maintain command and staff "colleges" at both intermediate and senior levels. Officers specifically selected for advancement attend these colleges. Post-graduate education of this sort includes specific training for the performance of large-scale military operations, general courses in the history and technology of military operations, and wide-ranging instruction in the many economic, political, and social factors involved in national security.

C. DESIGN AND DEVELOPMENT OF MILITARY TRAINING

The rapid changes in technology, tactics, and missions that are characteristic of today's military operations require matching agility in the design and development of training and education programs. These changes must be made quickly and efficiently. The U.S. defense community recognized this need early and began to apply the techniques and processes of systems engineering to the design and development of training. Systems engineering had served the DoD well in a host of other applications, and it provided a foundation for R&D that produced Instructional Systems Development (ISD) (Logan, 1979) and, more recently, Systems Approach to Training (SAT) (Guptil, Ross, and Sorenson, 1995).

ISD/SAT approaches apply standard systems engineering to the development of instructional programs. They extend the generic systems components of analysis, design, production, implementation, and evaluation to training and education. ISD/SAT combines these engineering components with theories of learning and instruction to produce systematically designed and effective training programs.

- Training *analysis* is based on systematic study of the job and the task(s) to be performed. It identifies training inputs and establishes training objectives to be accomplished in the form of student flow and in the knowledge, skill, and attitude outcomes to be produced by the training.
- Training *design* devises the instructional interactions needed to accomplish the training objectives identified by training analysis. It also selects the instructional approaches and media used to present these interactions.
- Training *production* concerns the development and preparation of instructional materials. These materials can include hardware (e.g.,

simulators), software (e.g., computer programs and audiovisual productions), and databases for holding information (e.g., subject matter content and the performance capabilities of military systems ranging from tanks and airplanes to radios and parachutes).

- Training *implementation* concerns the appropriate installation of training systems and materials in their settings and attempts to ensure that they will perform as designed.
- Training *evaluation* reflects the outcomes of the training against its objectives. It determines if the training does things right and if it does the right things. It verifies that the training system meets its objectives, provides the validation that meeting these objectives prepares individuals to perform targeted tasks or jobs better, and improves the operation of the organization overall.

Tennyson and Foshay (2000) discuss these processes in more detail. They have become as widely recommended and used in civilian education and training as they have in the military. In applying them to the preparation for military operations, training managers start from the top, with the missions and operations that military organizations at each level are designed, manned, supplied, and expected to perform. This beginning leads directly to the identification and description of all the tasks that the organization (and the men and women in it) must perform to accomplish its missions and operations successfully. The compilation of tasks for any given organization can be described as its mission-essential task list (METL). A military organization's METL forms the basis for its training plans.

Identification of the METL for an organization is only part of the story. Trainers must establish baseline conditions under which each mission-essential task must be performed and the standard of performance that determines successful performance of the task. This combination of tasks, conditions, and standards provides the basis for much of today's military training. The training readiness of individuals and their organization is determined by performance on mission-essential tasks, each of which is further defined by conditions and standards.

Analogous applications involving the development of essential tasks, conditions, and standards and their use in assessing the organization's training and educational "readiness," or likely success in performing its functions, are easy to imagine. However, this extended application of ISD/SAT is rarely found outside the military.

D. ASSESSMENT OF MILITARY TRAINING

Many individuals in the military and civilian training communities are familiar with Kirkpatrick's (1987) steps or levels of evaluation. These levels can be described roughly (and briefly) as shown in Table III-2.

Table III-2. Kirkpatrick's Four Levels of Evaluation

Level	Description	Evaluation Issue
1	Surveys	What did people think of the training?
2	Training Outcome Measures	Did the training achieve its objectives?
3	Transfer	Did job/work performance improve?
4	Benefits	Did organizational performance improve?

These four steps are as relevant to military training as they are to civilian applications, and they are applied with about the same frequency in military training as they are in civilian training. Many assessments of military training stop at Level 1, with surveys of the trainees and instructors. Some proceed to Level 2, with end-of-course measurement of the knowledge and skills provided by the training. These are the topics of reviews such as those by Orlanksy and String (1977, 1979) and meta-analyses such as those by Fletcher (1990). A few assessments of military training extend to Level 3, with measurement of on-the-job performance improvements; however, those that do are often limited to opinion surveys of peers and supervisors and rarely involve genuine measurement of job performance.

One point emphasized by Kirkpatrick's levels is that training—military and civilian—is a means to an end. Whatever excellence we achieve in training design, development, and delivery will remain irrelevant if the end it serves is not achieved. Hence, Level 4.

At Level 4, civilian trainers consider issues such as productivity and profitability. Military trainers must consider operational effectiveness, which keys on combat effectiveness. Hiller's (1987) criterion problem helps explain the scarcity of Level 4 assessments in military training evaluations. A few Level 4 evaluations of military training have been undertaken to link training inputs with operational effectiveness. For instance, Cavaluzzo (1984) found that a 1-percent increase in flying hours was associated with a 0.5-percent decrease in average bombing miss distance; Hammond and Horowitz (1990) found that a decrease of 10 percent in flying hours increased the probability of defeat in air-to-air combat by 9.2 percent; and Holz, O'Mara, and Keesling (1994) found that the

number of tank miles driven was correlated with offensive mission performance ($r = 0.68$) and defensive mission performance ($r = 0.80$).

With today's mix of missions, which include peacemaking, peacekeeping, counterterrorism, and humanitarian relief, the inclusion of Level 4 assessments for military training inputs are increasingly feasible as these missions become increasingly common for all nations' military organizations. They should be pursued. However, the heart of military capability remains effectiveness in armed engagements. Level-4 evaluation of training for this capability will remain difficult for all military organizations.

Kirkpatrick and others who are concerned with the evaluation of training and education emphasize instructional effectiveness. There is another side of the coin, however. Assessments are performed to inform decisions—in this case, decisions about training. The hallmark of most, perhaps all, decision making is not just the business of seeking improvement but also determining what must be given up to achieve it. Here, we encounter the issues not only of effectiveness, but of costs and cost effectiveness.

E. COST, EFFECTIVENESS, AND COST EFFECTIVENESS

Most evaluations of new instructional approaches are performed by instructional researchers and innovators who simply want to know if a new approach works and if it works better than what they now have. For managers and policymakers, this is only half the story. Increasing effectiveness is important, but systems are closed and budgets are limited. Decisions about the allocation of scarce resources among competing alternatives to maximize organizational goals and objectives are a perennial necessity. Such decision making is as common in military training as it is elsewhere.

The cost effectiveness of training appears to be more frequently and openly discussed in the military than in the civilian area. This difference may be associated with the nature of nonmilitary training, which generally occurs in the profit-and-loss world of business and industry, where training is performed to achieve proprietary advantage. Military training is supported with public funding and is intended to meet national objectives. For this reason, its costs, effectiveness, and findings are more open to public review and discussion. Certainly, its principles and lessons learned should be open to all. This is particularly true for costs and effectiveness, which are sensitive topics for business and industry. Whatever the case, most freely available information on the cost effectiveness of different training approaches seems to emerge from military applications.

Cost-effectiveness considerations may highlight one dimension of difference between education and training. Education, as an end in its own right—something done for its own sake—is often concerned with the maximization of effectiveness given fixed costs. Training, as a means to an end, is often concerned with minimizing costs to achieve a given level of effectiveness. These differing approaches to questions of cost effectiveness appear valid—but only up to a point. Educators do have objectives, and educational decision makers do have an interest in minimizing costs to achieve them. Trainers operate from fixed budgets. They have an interest in squeezing the most instructional effectiveness they can from these budgets. Military trainers, as interested as they must be in minimizing costs, increasingly and naturally emphasize effectiveness rather than costs as the preparations for armed combat come closer.

Whatever the case, those whose assessments are intended to inform decisions concerning the adoption of training programs must consider costs and effectiveness. Even researchers, who want to know if their new ideas "work," must consider costs if they wish to make a difference in practice and influence training decision makers. Studies that fail to consider both costs and effectiveness are insufficient for making organizational decisions and setting policies.

Allocation of instructional resources or expenditures in military and nonmilitary applications is based on economic analysis, a technique to help resource allocation decisions attain maximum efficiency. The assumption here is that there is a combination of resources that maximizes instructional productivity and uses minimum resources. Maximum instructional efficiency has been attained when the combination of resources that will improve instructional productivity without increasing instructional costs cannot be found. Economic analysis for training must assess the repertoire of approaches available to achieve maximum instructional efficiency.

The basic idea behind economic analysis is the well-established and straightforward notion that there is no free lunch. The economic analyst looks for opportunities in selecting any alternative. This suggests, as did Okun (1970) when he articulated the approach, that the economic analyst pursues a marginalist or incrementalist approach. The economic analyst must insist on knowing how much is gained and how much is given up by doing something different.

Economic analysis incorporates the concepts of cost-benefit analysis and cost-effectiveness analysis. Cost-benefit analysis is generally used to determine if the benefits of projects and policies outweigh the costs. The assumption underlying cost-benefit

analysis is that both costs and benefits are measurable in the same units, which are usually monetary units such as dollars. This commensurability is a prerequisite for cost-benefit analysis.

The full benefits of instruction may be impossible to assess in monetary units, despite heroic attempts by economists to do so. Commensurability that adequately reflects the benefits of instruction is difficult to attain in comparisons of instructional alternatives and their outcomes. The problem is particularly difficult in light of Hiller's criterion problem and associated inadequacies in our measures of unit readiness to perform military operations.

When commensurability is lacking, cost-effectiveness analysis is used. Again, costs are usually expressed in monetary units such as dollars. Benefits (e.g., information retention; the productivity, job knowledge, and motivation of workers; favorable supervisor ratings; and the productivity and effectiveness of the client organization) are measured in their own units, usually along as many dimensions as possible to reflect the full spectrum of instructional outcomes.

In performing cost-effectiveness analyses for instruction, a common practice is to hold either costs or effectiveness constant and observe variations in the other variable across the alternatives being considered. Often the variable is not actually held constant but is simply assumed to be the same across the alternatives. There are evaluations in which cost of competing alternatives is implicitly assumed to be the same, and there are just as many evaluations in which the effectiveness of competing alternatives is implicitly assumed to be the same. Frequently, no data or information is presented to support the assumptions of equal costs or equal effectiveness, and decision makers must take it on faith that the assumptions are warranted.

These considerations of cost and effectiveness lead naturally to the question of what can be done in real practice. One necessity in measuring the costs of instruction is a practicable list or "structure" of well-defined cost components. These have been called ingredients by Levin (1983) and elements by Knapp and Orlansky (1983). The list should, for any instructional alternative, capture all the components needed for cost-effectiveness comparisons regardless of the scope, complexity, or technology of the alternative. It should also ensure in the analysis a level of detail that clearly identifies the "cost drivers"—the major contributors to the cost of the alternative. The list should be usable for selecting, planning, assessing, and modifying instructional alternatives.

Four general categories are found in most cost models:

- **R&D.** R&D costs consist of all hardware, software, other materials, people, and facilities necessary to create, test, and evaluate an instructional approach.
- **Initial investment.** Initial investment costs comprise the one-time costs of procuring and deploying resources in the quantities needed to satisfy anticipated requirements for an instructional approach.
- **Operations and support (O&S).** O&S costs include those needed for managing, operating, and maintaining an instructional approach after it has been implemented.
- **Disposal and salvage.** Disposal and salvage costs comprise the one-time costs of removing the instructional approach from operational use.

In practice, R&D costs are set aside as being too hard to determine, too difficult to recover, and basically "sunk." There is little to decide about the resources that have been expended. Disposal and salvage costs are relevant in several areas, but these costs tend to be minor in training programs. They, too, are usually set aside. What remain are initial investment and O&S costs. These two categories of costs should be included in cost-effectiveness analyses intended to inform about choices to be made among different instructional approaches. Knapp and Orlansky (1983) developed a comprehensive cost element model for evaluating training systems. It provides a common basis for cost evaluations and cost comparisons of training programs and should be practicable for training applications inside and outside the military.

Basically, three questions need to be answered:

1. How much more or less effectiveness does the new technology, device, or method of training provide?
2. How much more or less does the new technology, device, or method of training cost?
3. If the new technology, device, or method improves the effectiveness of training, is the improvement worth its cost?

Kazanowski (1968) developed a standardized, 10-step approach to cost-effectiveness evaluations. The approach, which was developed for selecting weapons system capabilities, provides a foundation for evaluating cost-effectiveness in instruction. Kazanowski's 10 steps applied to instruction might be described as follows:

- **Step 1: Define the objectives.** Training objectives are most often expressed in terms of what students can do (skills), what they must know (knowledge),

and/or the attitudes they must possess after they finish the instruction. In training, the objectives can be derived directly from the skills and knowledge required to perform a job. In the absence of these objectives, relevant, systematic design, development, implementation, and evaluation of the instruction is unlikely.

- **Step 2: Identify the mission requirements.** The instructional system must possess productivity, or “pipeline,” characteristics defined by its mission. It must be able to churn out a given number of graduates within given amount of time. The instructional mission determines these pipeline requirements.
- **Step 3: Develop the alternatives.** Once the instructional objectives for student outcomes have been defined and the pipeline requirements of the instructional program have been established, locating or devising alternative approaches for satisfying these objectives and requirements is appropriate. Generating alternatives is a critical activity and requires considerable imagination and creativity. Tools and aids that help are available, but no sure procedures for developing comprehensive sets of instructional alternatives exist.
- **Step 4: Design the effectiveness evaluation**. The measures to be examined by an effectiveness evaluation should be well defined and evident. These measures should follow directly from the instructional objectives and pipeline requirements established for the program.
- **Step 5: Select a fixed cost or fixed effectiveness approach.** As discussed previously, trainers are likely to hold effectiveness constant and try to minimize cost to achieve that level of effectiveness, whereas educators are more likely to hold cost constant and try to maximize effectiveness to be obtained for that cost. It is possible to avoid choosing between fixed cost and fixed effectiveness approaches by calculating and then comparing ratios of cost to effectiveness or ratios of effectiveness to cost for the various alternatives. A ratio approach of this sort is appropriate only when cost and effectiveness that are increments to some baseline are being considered, and, even then, significant methodological caution is advisable.
- **Step 6: Determine the capabilities of the alternative systems.** Once the measures and evaluation approach has been settled, it is time to gather the data and proceed with the analysis.
- **Step 7: Tabulate the alternatives and measures.** The alternatives are usually tabulated following the “northwest” rule. That is to say, the measures are listed from left to right in decreasing priority, and the alternatives are listed from top to bottom in order of decreasing apparent value.

- **Step 8: Analyze the merits of the alternative systems.** Decision makers need information. Discussing the findings, evaluating the strengths and weaknesses of the data collection procedures, and assessing the alternatives in light of the evaluation should be pursued.
- **Step 9: Perform a sensitivity analysis.** The outcome of a cost-effectiveness evaluation may or may not be sensitive to the assumptions on which it is based. Sensitivity analyses should be performed to assess this possibility.
- **Step 10: Document the bases of the previous nine steps.** The range of issues and concerns ensures that no cost-effectiveness evaluation will satisfy all those who have a stake in its outcomes, but it can and should be explicit. Decision makers should know its strengths and limitations. Underlying models of cost and effectiveness should be documented so that decision makers can determine how relevant any analysis is to their concerns.

F. ENGINEERING OF INSTRUCTION

Finally, just as there is a range of cost measures to be considered in instruction, so is there a range of effectiveness measures. The end-of-instruction test, typically used to evaluate the effectiveness of instruction, rarely reflects the full range of outcomes instructional managers and other decision makers expect in return for their investment in the program. These outcomes include speed of response, accuracy of response, short- and long-term retention of performance and knowledge, ability to transfer performance and knowledge to new situations, insight and the ability to teach others what was learned, adherence to procedure, and motivation to improve performance and knowledge in the subject area. Which subset of these objectives ought to be measured depends on the intentions of training decision makers. Different measures could be used to evaluate the same instructional program depending on these intentions.

Woolf and Regian (2000) further discuss the engineering of instruction and its importance in designing training programs that are aligned with the needs and perceived utilities of any organization that implements them. Rather than repeat their discussion here, it may suffice to note that in addition to defining and describing an adequate model of costs in the assessment of training, an adequate model of training outcomes should be defined and described in assessing the contributions of any training program—military or otherwise—to its sponsors and users.

IV. VARIETIES OF MILITARY TRAINING

The extent and diversity of military training make it difficult to discuss coherently. General Paul Gorman suggested a robust partitioning of military training that continues to find wide use. As shown in Table IV-1, Gorman's matrix divides military training into four cells keyed to whom is trained (individuals or "collectives") and where the training takes place (in residence or in operational units). In DoD organizations, this structure seems to evolve almost inevitably as roles and responsibilities for the overall management and conduct of training evolve.

Table IV-1. Gorman's Matrix: Components of Military Training

	Where Training Takes Place	
Who is Trained	**Residence**	**Operational Units**
Individuals	Training conducted by training organizations to develop individual skills and knowledge in formally convened, centralized settings	Training conducted by operational units to develop individual skills and knowledge in distributed settings
Collectives	Training to achieve crew, team, and unit performance standards in formally convened, centralized settings	Training to achieve crew, team, and unit performance standards in operational units and other distributed settings

A. INDIVIDUAL AND COLLECTIVE TRAINING

Training objectives can center on the performance of either individuals or teams. Most research and studies of learning and teaching center on individuals. However, as suggested by Cannon-Bowers, Oser, and Flanagan (1992), among others, most human activity is performed by collectives: crews, groups, teams, and units. In military and nonmilitary activities, the skill and performance of collectives, rather than the individuals who compose them, are the ultimate objects of training. In this perspective, most, if not all, training of individuals is intended only as a means to produce successful—competent and proficient—collectives.

A fair question for research is whether the performance quality of the collective whole (e.g., the crew, team, or unit) differs from the summed capabilities of the individuals who comprise it. Collective performance ultimately depends on the performance of

individuals. We should, then, expect to find empirical connections in the research literature between the performance of collectives and the assessment of individuals who comprise them. Several studies meet these expectations.

Comrey (1953) found that individual manual dexterity accounted for 44 to 51 percent of the variance in the performance of two-man teams performing a cooperative manual dexterity task. McGrath and Altman (1966), in their review of small-group research, reported that individual measures of job experience consistently and strongly accounted for collective success. O'Brien and Owens (1969) found that group members' abilities accounted for about 34 percent of the variance in their productivity on highly coordinated tasks. Jones (1974) showed that individual effectiveness accounted for 36 to 81 percent of the variance in the success of tennis, football, baseball, and basketball teams. Tziner, Houser, and Hoffman (1985) determined that increases in the ability and the motivation of the individuals comprising three-member tank crews significantly improved their performance of military tasks. These and other studies indicate that collective performance can, to some degree, be predicted from individual capabilities when a collective task engages the skills and knowledge of individual members and these skills and knowledge are reliably measured.

On the other hand, the amount of collective performance *not* accounted for by assessments of individual members is also notable. Reviews by O'Brien and Owens (1969), Dyer (1984), and Kahan et al. (1985) concluded that the ability to predict collective performance from individual member capabilities is substantially reduced when substantial member interaction is required. Stout, Salas, and Carson (1994) directly examined the impact of coordination requirements on the performance of two-person teams. Interactive processes required by their task included behaviors such as providing information in advance, making plans, asking for input, assigning tasks, and initiating assistance to others. Stout et al. found that coordination ratings for the teams accounted for 26 percent of their performance variance after the individual abilities of the two-team members were partialled out.

There should also be some component of collective performance that cannot be accounted for by individual-level skills but, rather, by the matches—the complementation—of the individual-level skills going into it. This component, which Roby and Lanzetta (1958) called the "assembly effect," may further account for the fact that the capabilities of individual team members can determine only a part of team performance. The assembly effect is understood at some level by successful coaches and military

commanders. The magnitude of the assembly effect may be a direct measure of the amount of “teamness”—the amount of coordination and communication—required to meet the team objectives.

The training issue remains unanswered. Should we train the individual or the team? Military trainers try to do both, but the point at which training for collective performance must pass from individual training to training within the collective remains poorly understood. Perhaps all teaming skills can be trained individually, or perhaps individuals can only master the collective skills of communication, coordination, and timing by training within teams. The answer most probably depends on the type of team to be trained.

B. RESIDENTIAL AND UNIT TRAINING

The unique characteristics of military life and culture require newly recruited military personnel to undergo some early training to prepare them for positions in operational military units. Much of the initial transition from civilian to military life involves an enculturation. Despite the emphasis on military courtesy and discipline in this early training, a substantial body of hard-core skills and knowledge has to be mastered. As the training proceeds, it increasingly emphasizes the certification of individuals for specific military occupational specialties.

Training is never complete. Continued growth in skill and knowledge is required as careers advance. Individuals may transfer to different military occupational specialties. They may require training to operate, maintain, or deploy specific and unique systems found in their operational units. They may train to prepare for unit-specific missions. They will certainly advance in rank and require training to prepare for new responsibilities occasioned by their growing maturity, competencies, and military stature. They may receive follow-on training from their units, from specialized training organizations to which they return, from manufacturing representatives, or from mentors in on-the-job training. The distinction of residential vs. unit training concerns whether individuals are trained by specialized training organizations or by the operational units to which they have been assigned.

Either form of training (residential or unit) can be accomplished to some extent by distance or distributed learning techniques. That is, either can be performed without the physical presence of a human instructor. This training can be accomplished synchronously, usually through either one- or two-way video teletraining (VTT) supplemented by

two-way audio. This approach transcends locality but still requires students to assemble at particular times and places in classrooms.

Distributed training can also be performed asynchronously, often using one form or another of CBI perhaps supplemented by multimedia or "intelligent" tutoring capabilities. It can be delivered by mailed media such as videotape, CD-ROM, or even paper-based correspondence materials. Notably, it can be delivered through the Internet over the World Wide Web. All these possibilities for asynchronous training transcend both locality and time. Much U.S. DoD training is now being converted from classroom-based, synchronous training to asynchronous training through the use of instructional technology.

1. Residential Training of Individuals

Residential training of individuals is often called "schoolhouse training." This type of training uses procedures and techniques that are most like those found in civilian education and training. It is provided by military schools in military units whose primary mission is to conduct training. It is intended to develop the skills, knowledge, and attitudes needed to certify individuals for the performance of specific, identifiable jobs. It often results in certification, such as the awarding of an occupational rating (air traffic controller, military policeman, radar repairman) or subspecialty within an occupational rating (parachute/airborne qualification, specific language ability, specific equipment qualification, higher-rated skill level).

2. Unit Training of Individuals

Unit training of individuals typically occurs after individuals are assigned to operational units. This training is typically conducted by those units—not by military training commands. Its instructors are usually individuals who are also assigned to the operational unit. It usually assumes that students have received initial skill training, that they have completed much of the transition from civilian to military life, and that unit training should build on their initial training by increasing the breadth and depth of their skills and knowledge. Like residential training for individuals, unit training of individuals is intended to prepare individuals to perform identifiable jobs, but these jobs are determined by the specific billets and equipment found in the unit. Unit training is specifically designed to meet unit needs and probable mission requirements.

3. Residential Training of Collectives

As noted previously, nearly all military operations are accomplished by collectives—by individuals acting as members of crews, teams, and units. Much of this training is viewed as the responsibility of local commanders and is conducted within units. Some of it, however, is conducted outside local units by organizations whose primary mission is the training of collectives. For example, antisubmarine warfare (ASW) teams may be taken off ships and trained as teams in land-based simulators intended to provide intensive practice exercise with feedback in ASW operations. Another prominent example comes from the U.S. Army's National Training Center (NTC), which brings battalions and brigades to Fort Erwin, an instrumented range just south of Death Valley in California, to engage in what is typically two weeks of exercises against a permanent, on-site opposition force that functions under the tactical doctrine of probable U.S. adversaries. Skilled operator-controllers are scattered throughout the unit being trained and provide detailed evaluative feedback to all members of the unit in after-action reviews (AARs). Bolger (1986) provides an engrossing description of NTC operations.

4. Unit Training of Collectives

Historically, the unit training of collectives is the most typical form of military training. Residential schools prepare pilots, cooks, and infantry to some level of certified individual proficiency; however, the training they receive in units (to function as members of teams and crews, with the specific equipment, jobs, and individuals with whom they may perform military operations) is a prime responsibility of every unit commander.

V. SIMULATION

Military operations put at risk people (military and civilian), highly sophisticated, expensive equipment, national security, and international relations. We need to prepare individuals to perform these operations successfully while minimizing the dangers. What they must learn requires the application of knowledge and exercise of skills that cannot be sufficiently learned in lecture halls.

How then are they to learn and practice, with adequate feedback, the skills and knowledge they need to perform military missions? The answer must be found in simulation. Heavy reliance on instructional simulation is characteristic of military training.

Simulated environments permit training of a nature that cannot or should not be attempted without simulation. In simulated environments, aircraft can be crashed, expensive equipment can be ruined, and lives can be jeopardized in ways that range from impractical to unthinkable. Simulated environments also provide other benefits for training. They can make the invisible visible, compress or expand time, and reproduce events, situations, and decision points over and over. Simulation-based training is not a degraded reflection of the more realistic environments we would prefer to use. It allows us to train aspects of performance that would otherwise be inaccessible. It offers at least a partial solution to Hiller's criterion problem.

A. SIMULATION TRAINING FOR INDIVIDUALS

From the days of the medieval quintain and doubtless before, simulation has been prominent in conducting military training and assessing the readiness of individuals, crews, teams, and units to perform military operations. Today, simulation is as familiar to mud-weary soldiers participating in field exercises as it is to commanders maneuvering corps of computer-generated forces (CGF) sweeping across vast, electronic plains in our war colleges. It is supported by devices ranging from plastic mock-ups to laptop computers to full-motion aircraft simulators that cost more than the aircraft they simulate.

Some rough distinctions among models, simulators, and simulation is useful. Models provide the underlying representation of inputs and outputs. They are the engines that control and determine the responses of simulators and simulations to users.

Simulators are devices. They are intended to represent to the student other devices or phenomena likely to be encountered in the natural world and are used to produce simulations of the natural world. Simulations are the products of simulators and their underlying models. A simulation is a system of models and/or simulators that represents another system, environment, or situation.

B. SIMULATION AND TRANSFER

The realism, or "fidelity," needed for simulation to perform successful assessment and training is a perennial topic of discussion (e.g., Hays and Singer, 1989). Much of this discussion responds to the intuitive appeal of Thorndike and Woodworth's (1901) argument for the presence and necessity of identical elements to ensure the successful transfer of that which is learned in training to that which is needed on the job.

Thorndike and Woodworth suggested that such transfer is always specific (never general) and is keyed to either substance or procedure. More recent studies of transfer, such as the widely noted paper by Gray and Orasanu (1987) who remark on the "surprising specificity of transfer," echo this point of view. As Holding (1991) points out, the identical elements theory is one with which it is hard to argue. It seems reasonable to expect task elements mastered in simulation to be performed with some appreciable degree of success on the job.

For dynamic pursuits such as combat, where unique situations are frequent and expected, the focus on identical elements often leads to an insistence on maximum fidelity in simulations used for assessment and training. Because we do not know precisely what will actually happen, we assume that we must provide as many identical elements as we can. This prescription would suggest a viable approach if fidelity came free, but it does not.

As fidelity rises, so do costs (e.g., Miller, 1974; Holding, 1991). High costs can be borne but will also reduce the number, availability, and accessibility of valuable resources that can be routinely provided for assessment or training. Therefore, we must reduce costs by selecting the correct degree of fidelity needed to achieve our objectives. Notably, the choice is not simply high fidelity and high costs vs. low fidelity and low costs. The optimal choice is somewhere in between, and it keys on careful explication of training objectives. The processes of finding this optimal choice of fidelity based on training objectives usually cluster under the issue of "selective fidelity."

Simulation does appear to work. Improvements in the quality with which criterion tasks are performed and the probability that they will be performed at all can be partially accounted for by time spent in simulation. Evidence of this utility comes from many sources. In aircrew training, the issue keys on transfer: Are the skills and knowledge acquired in simulation of value in flying actual aircraft? That is, do they transfer from one situation to the other? Many attempts to answer this question rely on transfer effectiveness ratios (TERs) (as in Roscoe and Williges, 1980). These ratios can be defined for pilot training as follows:

$$\mathrm{TER} = \frac{A_c - A_s}{S} \quad ,$$

where TER = transfer effectiveness ratio, A_c = time required to reach criterion performance, without access to simulation, A_s = time required to reach criterion performance, with access to simulation, and S = simulator time.

Roughly, this TER is the ratio of aircraft time savings to the expenditure of simulator time. It tells us how much aircraft time is saved for every unit of simulator time invested. If the TER is small, a cost-effectiveness argument can still be made for simulation because simulator time is likely to cost much less than aircraft time.

Orlansky and String (1977) investigated this issue in an often cited study. They calculated 34 TERs from assessments of transfer performed from 1967 to 1977 by military, commercial, and academic organizations. The TERs ranged from –0.4 to 1.9, with a median value of 0.45. Orlansky, Knapp, and String (1984) also compared the cost of flying actual aircraft with the cost of “flying” simulators. Very generally, they found that (1) the cost of operating a flight simulator is about one-tenth the cost of operating a military aircraft; (2) an hour in a simulator saves about half an hour in an aircraft; so that (3) use of flight simulators is cost-effective if the TER is 0.2 or greater.

At one level, this finding is extremely useful and significant. However, nothing is simple, and a few caveats may be in order:

- As Provenmire and Roscoe (1973) pointed out, not all simulator hours are equal. Early hours in the simulator appear to save more aircraft time than later ones. This consideration leads to learning curve differences between cumulative TERs and incremental TERs, with diminishing returns best captured by the latter.
- Transfer is not a characteristic of the simulator alone. Estimates of transfer from a simulator or simulated environment must also consider what the training is trying to accomplish (the training objectives). This issue is well

illustrated in a study by Holman (1979), who found 24 TERs for a CH-47 helicopter simulator ranging from 2.8 to 0.0, depending on which training objective was under consideration.

- There is an interaction between knowledge of the subject matter and the value of simulation alone. Gay (1986) and Fletcher (1990) both found that the less the student knows about the subject matter, the greater the need for tutorial guidance in simulation. The strategy of throwing a naive student into a simulator with the expectation that learning will occur may not be viable.
- The operating costs of aircraft differ markedly and will create quite different tradeoffs between the cost effectiveness of training with simulators and without them. In contrast to the military aircraft considered by Orlansky, Knapp, and String, where the cost ratio was about 0.1, Provenmire and Roscoe were concerned with flight simulation for the Piper Cherokee, where the cost ratio was 0.73.

Other caveats may occur to the reader. Specific applications deserve specific attention.

The value of simulation is not limited to flight. We could also use TERs to assess the use of simulation in maintenance training. Time to effect repairs on actual equipment after using actual equipment in training could be compared with time to effect the same repairs after using simulated equipment in training. However, results reported from maintenance training assessments rarely report time to repair. Instead, results from "conventional" training involving lecture, textbooks, and hands-on experience with actual equipment are usually contrasted with training that replaces the actual equipment with simulated equipment. In these cases, effect size, which is the standard measure from meta-analysis used to quantify and combine results from independent and separate assessment studies, can generally be calculated and used (Glass, McGaw, and Smith, 1981; Hedges and Olkin, 1985).

From a broad review of interactive multimedia capabilities used for simulation, Fletcher (1997) extracted 11 studies in which simulated equipment was used to train maintenance technicians. These studies compared instruction with the simulators to instruction with actual equipment, held overall training time roughly equal, and assessed final performance using actual (not simulated) equipment. Over the 11 studies, the use of simulation yielded an effect size (which is the measure of merit in such meta-analyses) of 0.4 standard deviations, suggesting an improvement from 50th percentile to about 66th percentile achievement among students using simulation. Operating costs using

simulation were about 40 percent of those without it because the equipment being simulated did not break and could be presented and manipulated on devices costing one to two orders of magnitude less than the actual equipment that was the target of the training.

C. SIMULATION, COSTS, AND COST EFFECTIVENESS

Clearly, we would like to take account of costs and transfer effectiveness. We would like to allocate training time or trials between simulation and “hands-on” exercise with the intended equipment or situation, so that total costs to train are minimized. Approaches for solving this problem can be clustered under the heading of “isoperformance” (Bickley, 1980; Chronholm, 1985; Morrision and Holding, 1990; Jones and Kennedy, 1996). Basically, the idea is to devise a function, usually depicted as an isoperformance curve, showing every point where different combinations of training inputs produce equivalent performance outputs. The problem is then simply to find the point on the curve where costs are minimized. Of course, the full story is not that simple.

As suggested by discussions of the engineering of instruction (e.g., Woolf and Regian, 2000), the outcome of a training system is typically an integrated set of perceptual, cognitive, and psychomotor skills with supporting knowledge that permits an individual to perform a prescribed set of tasks or a job. Some of these skills may be present at the outset, some cannot be taught until the individual acquires prerequisite knowledge and/or skills, and some performance levels may be beyond the practical reach of individual learners. Learning is further complicated by the proactive and retroactive effects of other learned skills, learning losses that may differentially affect performance, individual learning styles, and individual learning rates. Optimal combinations of all these factors are desirable and cost-effective objectives for training system designers.

These combinations might be sought and perhaps found through an extended program of experiments intended to identify salient, high-leverage variables and assess their effects on training outcomes. Such an approach would be expensive, time-consuming, and disruptive. Faced with these real-world constraints, we may instead develop an empirically based *model* of the training system that incorporates interrelationships and analytical tradeoffs between various combinations of inputs, the costs of these combinations, and the training outcomes they produce. The validity of such a model—and its outputs—then becomes important issue, but it is not unreasonable to expect solutions presented by the model to be worth the effort to develop it.

As suggested previously, isoperformance relates two or more training inputs to a training outcome held at some prescribed value or level. It is generally assumed that each input by itself could produce the desired-level outcome, although some inputs could contribute uniquely to the outcome, necessitating at least some application of these inputs. Different amounts of the separate inputs can then be combined to produce the desired level of performance. Isoperformance identifies all combinations of the given inputs that produce a given output level of performance. This identification is usually done on a continuum, which produces an isoperformance curve in the case of two input variables and an isoperformace surface or "hull" in the multidimensional case of three or more inputs.

A common use of isoperformance is to assess different combinations of simulation and actual equipment training, as shown in Figure V-1. Total costs are shown in the upper curve. Performance that is the output of the training is expected to be the same everywhere on the total cost curve. Total costs initially decrease as simulator time is substituted for time on the (presumably more expensive) equipment and then increase as more and more simulator time is required to compensate for reductions in actual equipment time. Costs for actual equipment time start in the same place as total costs but then decrease monotonically as more and more simulator time is substituted in. Notably, they never reach zero because we assume that sooner or later the training program will have to include some time or trials with the actual equipment. Costs for simulator time start at zero and rise monotonically with the increasing use of simulator time or trials.

The cost-effective solution under this formulation is to find the minimum on the upper, total costs curve and use it to allocate training time or trials between simulation and the real equipment. In effect, it holds performance (or effectiveness) constant and tries to minimize costs. Carter and Trollip (1980) illustrate the other side of the coin. They used what Cronholm (1985) showed to be a mathematically equivalent approach to devise an optimal strategy for maximizing performance (or effectiveness again) given fixed costs.

Morrison and Holding concentrated on gunnery training. The main idea was to use simulation to save training ammunition. Other examples are possible. Bickley (1980) focused on simulator vs. flight time in the Army's AH–1 helicopter. Jones and Kennedy (1996) discussed the application of isoperformance functions for trading off personnel

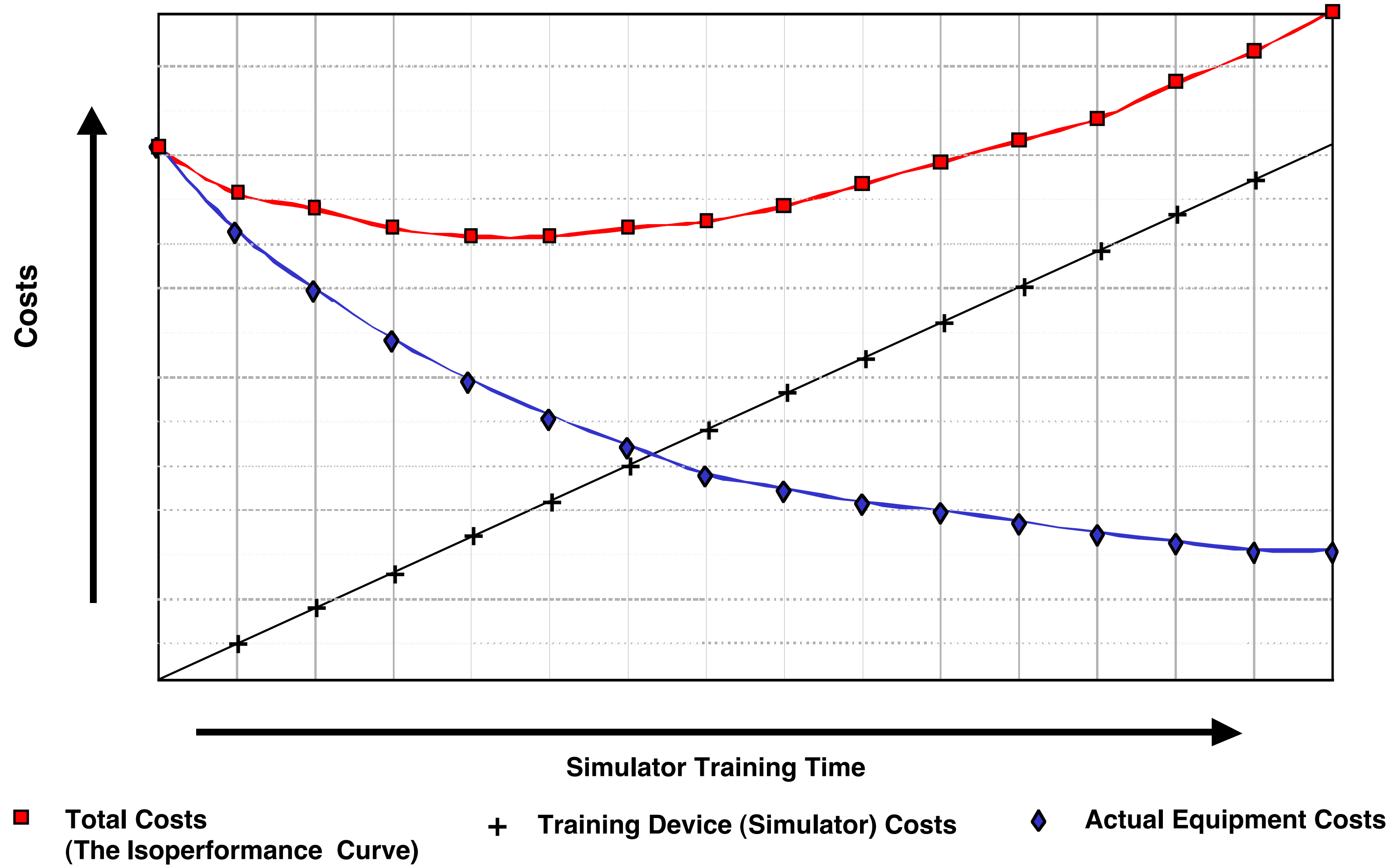

Figure V-1. Components of the Total Cost Function
(Adapted from Morrison and Holding, 1990)

aptitude against training time. Other applications can be expected as the use of these functions increases; however, the serious problem of collecting appropriate transfer data remains to be solved.

Adequate data collection to perform valid isoperformance analyses—data that show all combinations of training inputs that produce equivalent performance outputs—can easily swamp a training developer's budget. One well-precedented solution for this sort of problem is to substitute the judgment of experts for the empirical data that are needed. Morrison and Holding reviewed these possibilities and concluded that neither approach, by itself, is satisfactory. Findings from empirical study are sufficiently valid but prohibitively expensive. Expert judgments are relatively inexpensive but of dubious validity. The answer may lie somewhere in between. We may be able to increase the validity of experts' judgments by informing and shaping them with limited but valid empirical data. Guidelines for implementing such an approach remain to be developed.

VI. SIMULATION TRAINING FOR COLLECTIVES

A. SHARED MENTAL MODELS—AND SIMULATIONS

Training for collectives has recently centered on the issue of shared mental models. By mental models, researchers have in mind "mechanisms whereby humans are able to generate *descriptions* of system purpose and form, *explanations* of system functioning and observed system states, and *predictions* (or expectations) of future system states" (Rouse and Morris, 1986, p. 349). Shared mental models are then descriptions, explanations, and predictions that the members of a group, such as a military crew, team, or unit, hold in common. Cannon-Bowers, Salas, and Converse (1993) suggest that the presence and validity of these shared models determine, to an appreciable extent, the success of group operations.

The issue may extend beyond shared mental models to something that might be called shared mental simulations. Over the past 30 years, general theories of perception and learning have changed. They have evolved from the fairly strict logical positivism of behavioral psychology, which emphasizes the study of directly observable and directly measurable actions, to what may be called cognitive psychology. Cognitive psychology gives more consideration to internal, less observable processes that are assumed to mediate and enable human learning and to produce the directly observable behavior that is the subject of behaviorist approaches.

The keynote of these notions, which currently underlies our understanding of human perception, memory, and learning, may have been struck by Ulric Neisser (1967), who stated, "The central assertion is that seeing, hearing, and remembering are all acts of *construction,* which may make more or less use of stimulus information depending on circumstances" (p. 10).

Neisser came to this point of view because a large body of empirical evidence showed that many aspects of human behavior, such as seeing and hearing, simply could not be accounted for by external physical cues reaching human perceptors, such as eyes and ears. Additional processes, including an internally (one might say cognitively) generated *analysis by synthesis* process, had to be posited to account for well-established and

observable human abilities to detect, identify, and process physical stimuli. Such a process requires an active synthesis of the environment based on a runnable cognitive model, or simulation, that is validated or modified as needed by cues impinging on sensory perceptors. It is the actively evolving cognitive simulation, not the stimuli alone, that is said to account for what the individual understands about the environment.

As information and data become available to collectives, they appear to be absorbed and integrated into a rapidly evolving collective simulation of the rapidly evolving external environment. The decisions that emerge then result from running the shared simulation forward under various scenarios and parameters set collectively by the collective to identify optimized courses of action. Members of the collective must therefore take responsibility for the correctness of their own models and for the ability of others to share them.

How, then, might we develop a common runnable model or simulation that will be shared by all members of a collective? One way may be to expose them to a full a set of common cues that are as characteristic as possible of the environment in which they must operate and allow them freedom to explore and develop their own accurate—and sharable—representations of that environment. Once again, simulation appears to be called for.

B. SIMULATION OF MILITARY OPERATIONS

Despite the paucity of Kirkpatrick's Level 4 assessments and the presence of Hiller's criterion problem, the heavy weight of historical, anecdotal, and partial databased evidence suggests that military training contributes appreciably to success in combat. Still, our evidence remains incomplete and indirect. It concerns preparedness—"readiness"—rather than effectiveness. It accounts poorly for morale and leadership. It tends to emphasize process (number of exercises completed, hours flown, miles driven) rather than performance (knowledge and skills attained). Commanders and training decision-makers are aware of these issues. They have been vigorous and inventive in seeking ways to assess readiness, training, and probable effectiveness in performing military operations, but evidence remains partial, indirect, and imprecise.

One area on which many agree is the simulation of combat engagements. A frequently cited finding on the military value of assessing and training human competence for military engagements involves the impact of the Navy's TOP GUN exercises (Gorman, 1990). During the air war over North Vietnam, roughly 1965–1973, the U.S.

Navy and U.S. Air Force flew aircraft of comparable capabilities. In fact, many of the aircraft used were exactly the same, armed with the same weapons. During the first 4 years of air-to-air combat, the Navy and the Air Force yielded an identical, and disappointingly low, ratio of North Vietnamese to U.S. aircraft lost: 2.2 to 2.4 North Vietnamese aircraft for every U.S. aircraft downed (as shown in Figure VI-1 for the period 1965–1968).

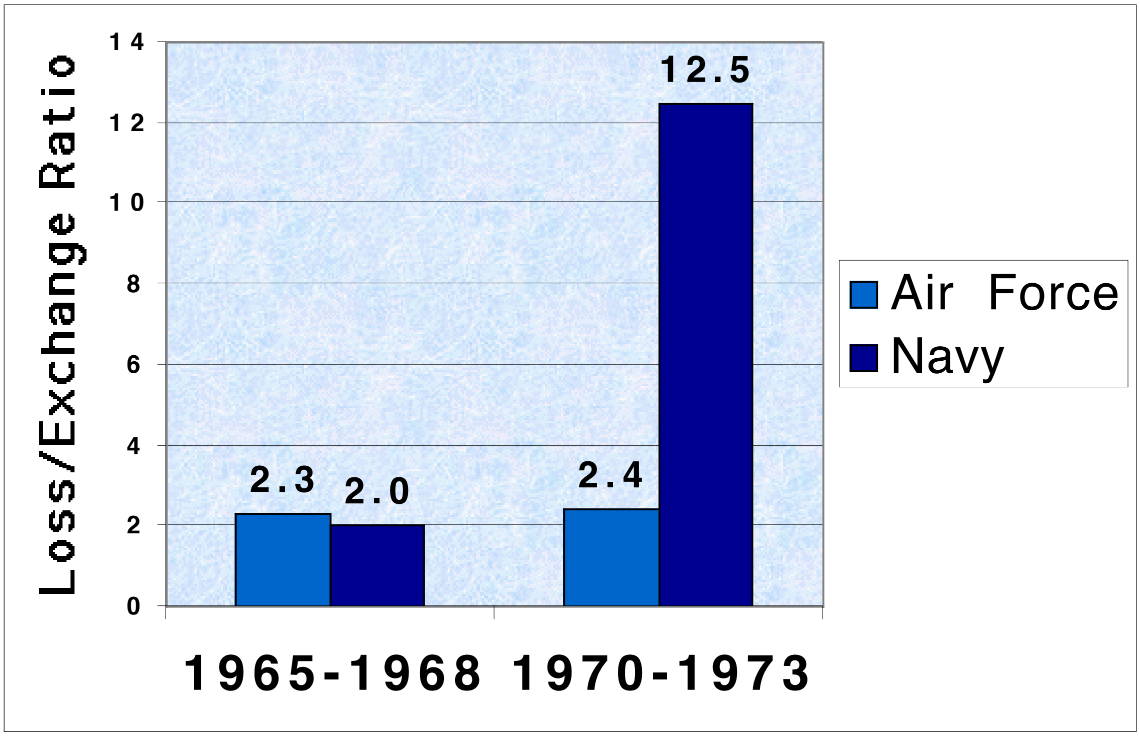

Figure VI-1. Loss and Exchange Ratios in U.S. Air-to-Air Engagements 1965–1973

From 1968 to 1970, there was a halt in combat operations over North Vietnam. During this period, the Navy initiated a training program using simulated engagements to reduce vulnerability in air-to-air combat. Navy student pilots were pitted against "enemy" pilots. Other Navy pilots trained in enemy tactics and flying MIG-type aircraft. Engagements were played and replayed until the Navy student flyers got them right.

This activity was perceived to have significant military value, but the question of validity remained. Did success in engagement simulation predict success in combat operations? The question was answered in 1970 when the air war resumed. As Figure VI-1 suggests, Navy pilots, still flying the same aircraft as their Air Force counterparts but trained using engagement simulation, performed about six times better than Air Force pilots, whose training had remained unchanged. As the figure shows, the new

loss-exchange ratios were 2.4 for Air Force pilots and 12.5 for Navy pilots. Given these results, the Air Force adopted a similar form of engagement simulation in 1974 for training its fighter pilots.

These results are promising because they suggest that success in simulation prepares individuals and collectives for real-world military operations. However, the approach is costly. It requires use of actual equipment (airplanes in the TOP GUN exercises, but tanks on the ground and ships at sea in other engagement simulations). Large numbers of individuals are also needed (e.g., to provide umpires and logistics support) for the training. The exercise range and equipment used are instrumented with position locators, lasers, and laser sensors to provide participants sufficiently accurate feedback on their performance so they can diagnose it and improve it.

These costs reduce physical accessibility, opportunities to train and assess performance, and availability of feedback. For instance, Army tactical teams at large unit levels, such as corps and division, train only about twice a year because of high costs and time demands (Garlinger and Fallesen, 1988). Less expensive means are needed to support readiness assessment. Networked simulation provides one such possibility.

C. TACTICAL ENGAGEMENT SIMULATIONS (TESs)

Today, everything short of combat engagements in which determined combatants oppose each other is viewed as simulation. Different forms of simulation are not viewed as inherently inferior or superior to each other. Their value keys on the objectives motivating their use. Defense planners distinguish among three forms of simulation: live, constructive, and virtual (Gorman, 1991).

Live simulation involves experience in the field (or in the air or at sea). Actual equipment is operated on ranges that are often instrumented to record relevant activities. Constructive simulation is best exemplified by computerized war games. Scenarios are established, and parameters are set and applied by participants who step back, let the computers play out the engagement, and then return to observe the results. Much therefore depends on the validity of the underlying model that controls the simulation. Virtual simulation is in between. It involves manned simulators that are linked together and that engage each other on common, electronically generated terrain.

The relationships among all three forms of simulation are worth noting (see Figure VI-2). This figure suggests the following:

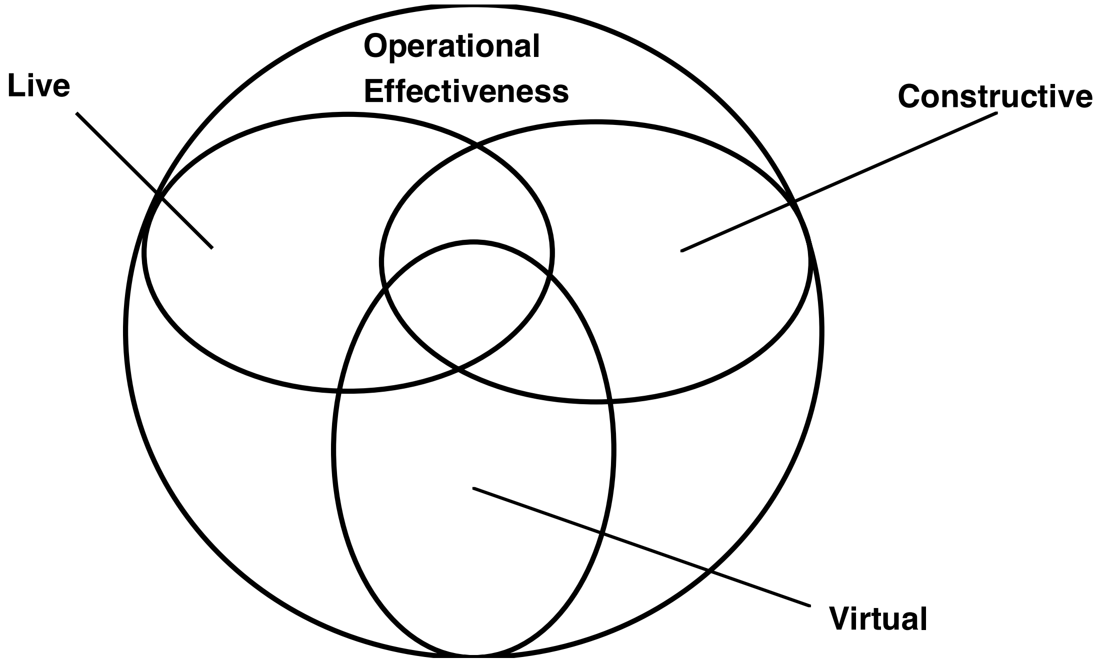

Figure VI-2. Relationship of Three Forms of Simulation to Each Other and to Operational Effectiveness

- Each form of simulation can train some, but not all, aspects of military operations. No form of simulation trains everything.
- There are aspects of operational effectiveness that none of these forms of simulation can train.
- Some aspects of operational effectiveness are trained by more than one form of simulation.
- Some aspects of operational effectiveness are uniquely trained by each of these forms of simulation. Put in very direct terms, no one form of simulation suffices as a criterion for the training provided by another. For instance, using live simulation to validate training performed in virtual simulation without reference to the specific aspects of effectiveness being trained is misleading.
- A related point is that some aspects of operational effectiveness are better trained by one form of simulation than another. For instance, maneuver may be better trained in virtual simulation than in live field exercises, where maneuvers may have to avoid constraints presented by highways, buildings, or shipping lanes that would be ignored during combat. Troop leadership skills may be better trained in the rain, snow, or desert heat of field exercises than in the air-conditioned buildings used for virtual and constructive simulation.

Trainers may actually be able to give something back in this area. Trainers are beginning to embrace emerging technologies that may be of interest to those concerned with personnel assessment. Among these, simulation is most prominent. It may allow us to collect data on the absolute rather than relative standing of individuals performing a sample of the whole job, with all necessary tasks integrated into the measurement. Among simulation, networked simulation seems to rise to the fore.

D. NETWORKED SIMULATION

Virtual, networked simulation was originally developed for training applications and was intended to improve the fighting performance of crews, teams, and units (Alluisi, 1991; Miller and Thorpe, 1995). The essential ingredient that networked simulation brings to the preparation of collectives is not so much initial instruction (although some can be provided), but an opportunity for accessible, frequent, and realistic practice with substantive, understandable, and relevant feedback. As its principal architect, Jack Thorpe (1987) stated, "This [concern with practice] emphasizes what we already know about how a team achieves mastery of its art, be it a sports team, an orchestra, an operating room team, or a combat team: Massive amounts of practice are demanded. There is no substitute" (p. 493).

Networked simulation consists of modular objects intended to simulate engaged entities. Typical entities are combat vehicles, such as tanks, helicopters, and aircraft, but the entities may be anything relevant, including bridges, buildings, dismounted infantry, and engineered obstacles. Simulators displaying these entities may be geographically located anywhere because they are modular and all share a common model of the situation and its terrain. In a networked simulation, a tank crew in a simulated tank in Germany can call for support from simulated aircraft in Nevada because they are being attacked by a helicopter simulator located in Alabama.

Each entity, along with hundreds of others, is connected to the network. If the simulated combat vehicles encounter allied vehicles on the digital terrain, they can join together to form a larger combat team and undertake a mission with all the problems of command, control, communications, coordination, timing, and so forth that such activity presents to tactical teams. If they encounter enemy vehicles, they can fight—engage in force-on-force combat engagements in which the outcome is determined solely by the performance of the individuals, crews, teams, and units involved. No umpires, battle

masters, or other outside influences are expected or permitted to affect the outcome of a networked simulation engagement once it begins.

In terms used by Wagner et al. (1977), networked simulation focuses on emergent rather than established task situations. There is no training "intelligence" in the core of this technology. Its use depends on the intentions of the user.

The individual members of crews, teams, and units who use networked simulation are assumed to be proficient in their individual skill specialties. They are expected to know how to drive tanks, read maps, fly airplanes, fire weapons, and so on at some acceptable threshold of proficiency before they begin networked simulation exercises. Moreover, the commanders of these crews, teams, and units are expected to possess some basic academic knowledge and practical skills in the command and control of their collectives. They are expected to know at some rudimentary level how to maneuver, use terrain in a tactically appropriate manner, fly helicopters, create and overcome engineered obstacles, and so forth. As Dyer's (1984) extensive review suggests, these prerequisite capabilities are essential for successful team training. Networked simulation focuses on collective rather than individual training.

All the digital communication packets used to control networked simulation can be recorded. With some exceptions implemented to reduce network communications traffic, entities currently issue three to five packets per second. Actions undertaken in networked simulation can then be recorded in extensive detail for later analyses and replay.

Characteristics of networked simulation especially useful in collective training are:

- **Focus on groups.** Networked simulation is intended to improve the performance of groups (i.e., crews, teams, and units).
- **Physical dispersion of participants.** Networked simulation allows participants who are geographically dispersed to engage and exercise with one another, without the expense and administrative complication required to bring them into physical proximity. Their dispersion is constrained only by the physical limits of the communication network that connects them.
- **Real-time responses.** The technology that underlies networked simulation is optimized for real-time responsiveness. It is particularly useful in simulating environments that demand responses to time-sensitive challenges that must be prioritized and met as rapidly as possible.

- **Emergent task environments.** Networked simulation was originally designed for tasks and activities that could not be prespecified in any deterministic fashion. These tasks evolve rapidly over time and in response to actions taken in the simulated environment. Communication and coordination within and between individuals, crews, teams, units, and commanders are free and uncontrolled. Outcomes are determined only by the participants' decisions and actions.
- **Accessibility of performance data**. Networked simulation allows massive amounts of performance data to be recorded and then easily retrieved, viewed, and assessed. Because all network packets can be recorded, performance archives can all be played and replayed using the same visual, simulated environment in which they were recorded but viewed from any vantage point desired. This capability for visual and highly detailed replay provides AARs in which actuality—rather than rhetoric or uncertain observation—drives feedback and adjudicates assessment.
- **Affordability.** Networked simulation is intended to be accessible and economically affordable.
- **Provisions for realism.** The environments supported by networked simulation increase some dimensions of realism by allowing human performance to determine outcomes, placing fewer constraints on force-on-force operations, reducing the quantity and impact of artificial conditions imposed by field activities, and increasing the freedom to undertake operations that would otherwise be too dangerous or costly.
- **Interaction with many entities.** Networked simulation allows its participants to interact with a large number of entities that must respond in a realistic fashion to their actions. These entities can be manned, computer generated but human controlled, or completely computer generated and controlled. The capacity for computer generation and control allows the number of entities involved to become sufficiently large to meet objectives that would otherwise be unaffordable and unattainable.

Networked simulation can currently represent three types of entities:

1. **Manned.** The principal entities are manned, or crewed, simulated combat vehicles—tanks, helicopters, and aircraft. All their key functions are directly controlled by humans.
2. **Automatic.** Some entities are strictly automatic. Once established or set into motion, no human intervention (by individuals, crews, teams, or units) can affect their operation. Examples of automatic entities in early versions of this technology were supply vehicles, which were requested and then after an appropriate (i.e., realistic) period of time would appear at the place requested.

They did not travel the terrain and, therefore, could not be attacked during transit in early versions of networked simulation.

3. **Semi-automatic.** The semi-automatic entities (mainly vehicles) of the semi-automatic forces (SAFOR) are among the most technically interesting, innovative, and challenging aspects of networked simulation. These entities are indirectly but not directly manned, or crewed. Human control is required for their operation at some level above that of crews—a platoon commander controls a platoon of unmanned vehicles, a company commander controls a company of unmanned vehicles, and so forth—and the entities must act and react in a realistic fashion. They must behave as they would if they were manned. Humans on the electronic battlefield should not be able to tell the difference between manned and SAFOR entities.

Although networked simulation was originally developed for training, it is finding applications in many other military activities. It is being used in the design, development, and acquisition of materiel and systems. For instance, we can include different performance capabilities proposed for military systems in force-on-force engagements to determine if the difference they make in combat effectiveness is worth their cost. Once prototypes are built, preparation for proposed tests can be rehearsed and fine-tuned using networked simulation before beginning trials in the field. Quick-strike missions can be repeatedly rehearsed in networked simulation using digitized terrain of the area where the military operations are likely to take place, simulation of the allied forces likely to be found there, and simulators locally positioned with the military units involved before they must be physically marshaled together.

Networked simulation appears to hold considerable promise for civilian applications. Among the possibilities discussed are (Fitzsimmons and Fletcher, 1995):

- **Training for crews, teams, and units.** Cannon-Bowers, Salas, and Converse (1992) documented the requirement to train crews, teams, and units in nonmilitary settings by citing examples of 21 such groups commonly found outside the military. These include quality circles, management teams, maintenance crews, product-development teams, cockpit crews, surgery teams, negotiating teams, instructor teams, and athletic teams. This list could easily be augmented by the inclusion of firefighting teams, well-drilling crews, police Special Weapons and Tactics (SWAT) teams, ship crews, disaster emergency teams, and ground-air control teams. Nearly all of these noncombat crews, teams, and units must exercise group coordination and communication skills to meet emergent situations with time-sensitive demands.

Networked simulation may also be key to make workplace training accessible and affordable. This need is especially great in small- to medium-sized firms, which have few resources to devote to producing and implementing the training and lifelong learning their workers need (U.S. Congress OTA, *Worker Training*, 1990). This need is also strongly felt by workers who, on their own, are attempting to improve their skills or transfer their skills to new areas of work. Teamwork, collaboration to solve motivating and job-relevant problems, access to subject matter experts (SMEs) and monitors, and, perhaps most importantly, development of learning communities in our workplaces can evolve from applications of networked simulation used to meet workforce training requirements.

- **School-to-work transition.** Transitions from school to work and occupational choices are often haphazard and uninformed. Students need to understand and directly experience the responsibilities and the rewards of the workplace and the "look and feel" of activity in specific occupations. Through networked simulation, students can enter into realistic workplace environments with their fellow students or with workers who have accumulated lifelong experience in these environments. They can experience in the virtual world the demands and workday challenges of entry-level positions along with the eventual satisfactions and rewards of many different occupations before committing to the training and other preparation they require for real-world participation. The school-to-work transitions that have been the target of much recent study and legislation will be eased considerably if students can readily access realistic experience with the variety of workplaces to which they might aspire.

- **Education.** Students in formal educational settings are seldom required to engage in real-time, collaborative interaction as members of problem-solving teams despite the instructional value of these experiences. Teachers depend on "chalk and talk" to convey information, and students are viewed more as passive recipients of learning than as active participants in a teaching-learning process. Classrooms continue to operate as isolated entities that provide few opportunities for networking or communication with the outside world. Educational applications for networked simulation are hard to find in practice, although they are not difficult to imagine.

  Despite this state of affairs, today's educators increasingly emphasize the value of collaborative problem solving, project-based learning, and learning by doing. New applications of technology in education, especially networked simulation, can support the inclusion of more group-oriented, concrete, and motivating instructional approaches. The most promising of these applications requires students to collaborate in solving problems. The students do not learn for the purpose of gaining abstract benefits in the

indefinite future but for more practically obvious and immediately motivating rewards. Students can collaborate with others in geographically dispersed locations, satisfy real-time constraints for coordination and response, access specialized information in remote digital libraries, perform experiments using virtual laboratories and laboratory equipment that outstrip locally available resources, and interrogate SMEs whose specialized knowledge they need to solve the problems.

E. AFTER-ACTION REVIEW (AAR)

A particularly interesting practice that has grown out of the use of TESs in military training is the AAR process. AARs are discussions held after a simulation exercise and are usually led by a controller or trainer from the exercise. They are intended to identify and discuss what happened in the exercise, why it happened, and how performance of the participants might be improved.

Notably, these AARs do not consist of performance critiques by the discussion leader. As practiced by the U.S. military, all discussion of what happened, why it happened, and how well it was done is expected to arise from those who were participants in the exercise, not from controllers or trainers. Further, the discussion leader and participants work together to ensure that their AAR proceeds in an objective and nonpunitive atmosphere of cooperation intended to improve future performance.

Many cultures outside the United States find this model of review difficult to implement. Points in U.S. AARs concerning strengths and weaknesses are raised frankly and may come as freely from subordinates as from superiors. Other cultures with more stringent class distinctions [e.g., those between officers, noncommissioned officers (NCOs), and enlisted; between lead pilots, wingmen, and ground controllers; or between different branches (e.g., infantry, armor, air defense) of the armed Service(s) involved] find this process too candid and freely discursive to implement. Still other cultures (e.g., those in which “saving face” is a sensitive and critical matter, those in which collective training performance is tightly bound to the career advancement of commanders, or those in which the free exchange of information is so rarely practiced that participants simply do not understand how to do it) also find implementation of the U.S. AAR process to be difficult, if not impossible. Cultures that can overcome these difficulties find payoff from this AAR process to be substantial. It stands as a powerful tool for improving military performance and likelihood of success in performing military operations.

Further, and as Morrison and Meliza (1999) demonstrate, the U.S. AAR process is well rooted in both basic and applied research. It represents a culmination of findings drawn from areas such as intrinsic and extrinsic feedback; performance measurement and self assessment; transfer of training, memory aiding, problem solving, decision making, and mental models; studies of group processes; social facilitation, identity, and cohesion; research on communication theory and techniques; guided discovery learning; and experiential learning, cooperative learning, and general systems concepts. Some of this research was applied directly to develop the AAR process, and some was used to support, focus, and rationalize techniques that were already being adopted on the basis of intuition, common sense, and 25 years of practice.

Education and training outside the military also review the processes and outcomes of simulation, instructional games, and other interventions involving groups, crews, staffs, and teams. As well-practiced and thoroughly rationalized procedures, the AARs conducted by U.S. military organizations may serve as a model for improving the productivity, competitiveness, and efficiency of many organizations beside those concerned with military operations.

VII. CONCLUSIONS

Military training, despite or perhaps because of its unique concerns, has its own perspectives and emphases, but many of these may be of interest outside the military training community.

A. TRAINING TECHNOLOGY

In one frequently cited study, Bloom (1984) reported on a series of experiments that suggested individual, one-on-one tutoring produces achievement that is about two standard deviations greater than that produced by classroom, one-on-many instruction. Like nearly all other forms of training, military training can rarely afford one instructor for every student. It has looked to technology to supply the individualization of pace, sequence, content, style, and difficulty that might account for Bloom's two sigma gap and help solve Bloom's two sigma problem.

This interest predates Bloom's investigations. It started with funding for CBI in the mid-1950s (Fletcher and Rockway, 1986) and continues through the present with the current ADL initiative intended to create web-available instructional objects that are reusable in courseware development, portable across technology platforms, durable across system software versions, and accessible to all stakeholders.

B. INSTRUCTION AS ENGINEERING

Training objectives are likely to be more identifiable, better defined, and less negotiable than those in education. As a consequence, training design and development principles are more concerned with producing predictable results than with the art of classroom presentation. Training elicits much creativity, but this creativity is more likely to be found in the inventiveness of design required to produce specific outcomes reliably and cost effectively than in the art of instructional delivery.

Military training is particularly concerned with enhancing its capabilities to engineer reliable training outcomes. Such an approach was infeasible before the availability and application of controlled presentations provided by instructional technology. Means of linking specific design decisions to specific training outcomes are now being

developed for military training. They may interest anyone concerned with reliable, predictable production of human capabilities and competencies through training.

C. TRAINING PRODUCTIVITY

Training productivity is not a matter of indifference outside the military. However, the military, which assumes a responsibility to train its people for their duties from enlistment through retirement, has concentrated on developing techniques and principles to increase training productivity. The military places few restrictions on disseminating its findings. In fact, in many cases, actively seeks to advance the state of training practices by promulgating them throughout the military training community.

Limitations, as noted, reside in the lack of incentives for spreading these techniques and principles beyond that community. Such information remains available through DTIC and NTIS. The emphasis in military training on developing techniques and procedures for examining the cost effectiveness of different training approaches and devising optimal combinations of these approaches to achieve training objectives may be of interest to training and education communities elsewhere.

D. COLLECTIVE PERFORMANCE

Most military operations and most human activities are performed in the context of collectives—crews, groups, teams, and units. The extent of emphasis on collective training is perhaps unique in the military. Most academic research on human learning, performance, and cognitive processes centers on individuals. Much research that is concerned with the learning, performance, and cognitive processes of collectives is accomplished to support military training. It has produced results that may be of general interest. Techniques for developing shared mental models, use of simulators and simulation to train collectives, processes for conducting AARs, and measures of the competence, productivity, and "readiness" of collectives should, among other developments, interest those in training communities well beyond the military.

E. RESEARCH AND DEVELOPMENT (R&D)

A point was made of the extent to which the military invests in R&D for training. It could be and has been argued that the major source of training R&D in the United States is military R&D. Still, the amount invested by the DoD is small relative to the size of the enterprise it supports. The proportion of R&D funding to the total DoD training

enterprise is about 0.1–0.2 percent. This contrasts with R&D in support of other areas of military activity, where similar proportions of effort range from 17 to 30 percent. The contribution of military R&D, proportionally small though it may be, is nationally important and worthy of national attention.

F. TRADEOFFS AND TRAINING AS A SUBSYSTEM

A point belabored in this document is that training is a means to an end. Training is, however, a subsystem of a more comprehensive system established to ensure the production and supply of human competence.

Training procedures and policies should not be set in a vacuum. The full system includes personnel selection for military service, classification of individuals for specific jobs, assignments to career-building responsibilities, training, human factoring and ergonomic design, job design, and supply and logistics procedures. All these subsystems interact. Higher standards for selection and classification will reduce training requirements. Training can compensate for poor ergonomic design, refined classification procedures can make up for recruiting difficulties, and so forth.

The evolution and development of military training will continue because it is a national priority. Its influence on training elsewhere has been substantial but indirect. It will continue to offer much in the way of techniques and technology to all training and education activities.

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GLOSSARY

AAR	after-action review
ADL	Advanced Distributed Learning
AFHRL	Air Force Human Resources Laboratory
ARI	Army Research Institute for the Behavioral and Social Sciences
ASW	antisubmarine warfare
BSEP	Basic Skills Education Program
CAI	computer-assisted instruction
CBI	computer-based instruction
CD-ROM	compact disk–read-only memory
CGF	computer-generated forces
CMI	computer-managed instruction
DDESS	Department of Defense Domestic Dependent Elementary and Secondary Schools
DoD	Department of Defense
DoDDS	Department of Defense Dependents Schools
DoDEA	Department of Defense Education Activity
DTIC	Defense Technical Information Center
EEG	Electroencephalograph
HumRRO	Human Resources Research Organization
I/ITSEC	Interservice/Industry Training System and Education Conference
IDA	Institute for Defense Analyses

IEEE	Institute for Electrical and Electronics Engineers
ISD	Instructional Systems Development
METL	mission-essential task list
NCO	noncommissioned officer
NPRDC	Navy Personnel Research and Development Center
NRC	National Research Council
NTC	National Training Center (U.S. Army)
NTIS	National Technical Information System
O&S	operations and support
OPTEMPO	operating tempo
OTA	Office of Technology Assessment (U.S. Congress)
R&D	research and development
SAFOR	semi-automatic forces
SAT	Systems Approach to Training
SIMNET	Simulator Networking
SME	subject matter expert
SOC	Standard Occupational Classification
SWAT	Special Weapons and Tactics
TER	transfer effectiveness ratio
TES	tactical engagement simulation
TR	Technical Report
USUHS	Uniformed Services University of the Health Sciences
VTT	video teletraining

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14. ABSTRACT

Military training means different things to different people. This document attempts to provide an overview of military training for people working in other areas of manpower, personnel, and instructional research. Military training uniquely emphasizes discipline, just-in-case preparation, and collective performance. Its relevance to other areas of personnel research are found in transferable products emanating from its research and development (R&D) investment; its contributions to instructional systems development (IDS); its techniques for incorporating costs, effectiveness, and cost-effectiveness in instructional assessment; and its concern with developing an engineering of instruction. The varieties of military training can be usefully classified into four categories: residential training of individuals, residential training of collectives, unit training of individuals, and unit training of collectives. Simulation is a major component of individual and collective military training. Methodologies such as transfer effectiveness ratios and isoperformance assessment have been developed to identify cost-effectiveness tradeoffs in training simulations. Innovative techniques with constructivist overtones for developing shared mental models, simulating military operations and tactical engagements, networking simulators, and providing after-action feedback have been developed for conducting simulation-based military training. These techniques are shown to be applicable to a variety of training settings, needs, and issues inside and outside the military.

15. SUBJECT TERMS

educational training, group and collective training, individual training, military training, training simulation, training simulators

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